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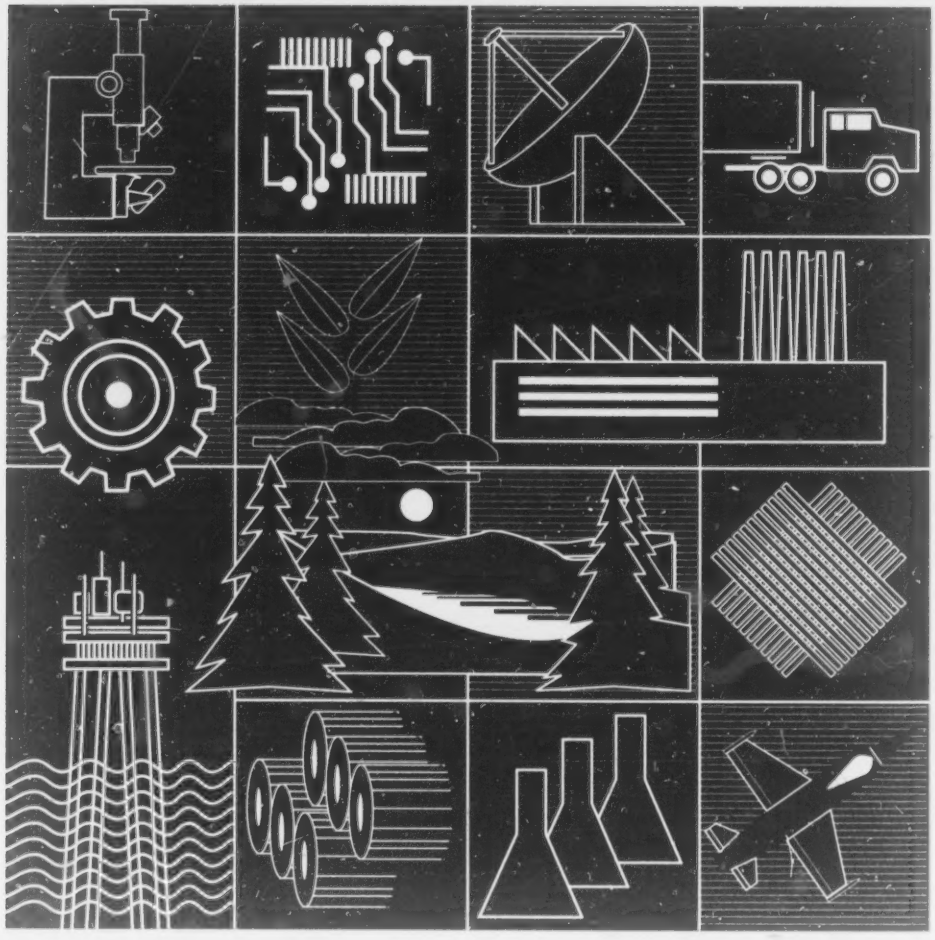
BATTELLE'S
R&D FORECAST



Probable Levels of
R&D Expenditures in 1991
Forecast & Analysis

Battelle
. . . Putting Technology To Work

This Battelle report is based upon a continuing study of U.S. expenditures for research and development. It was prepared by Drs. Jules J. Duga and W. Halder Fisher of Battelle Columbus Operations. Parts of the data presented here were derived from such sources as the National Science Foundation, published R&D data, and others.

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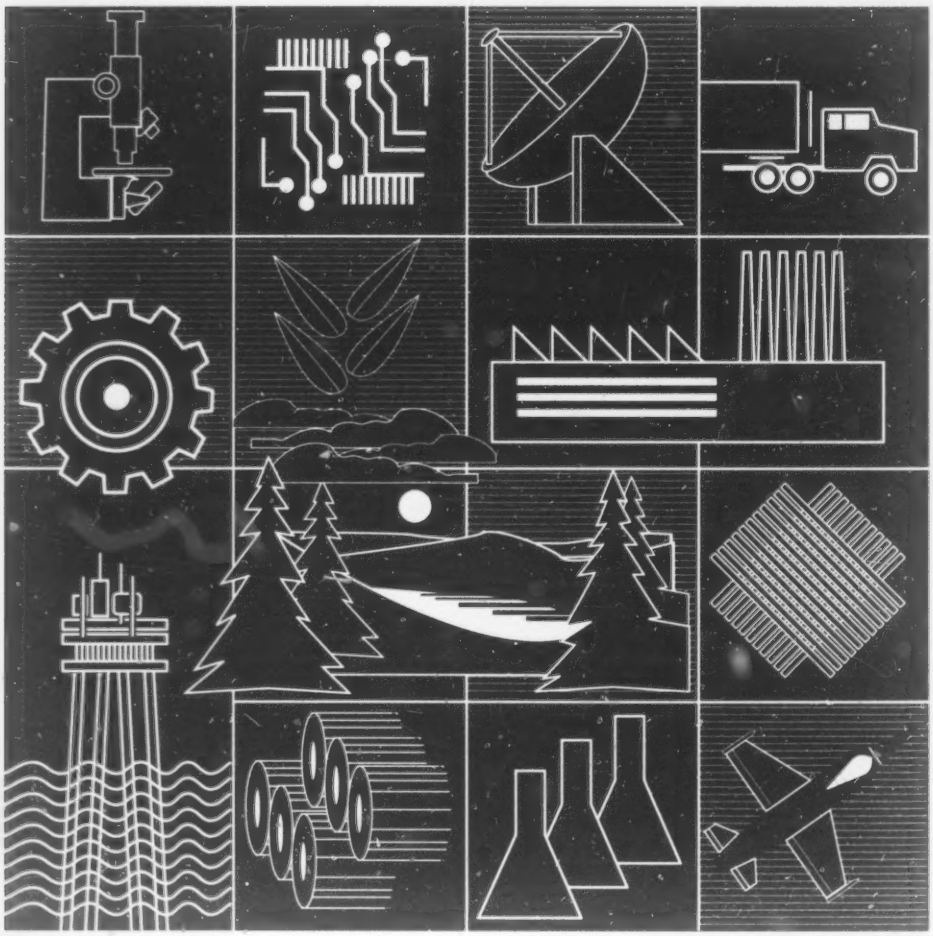

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PROBABLE LEVELS OF R&D EXPENDITURES IN 1991

SUMMARY OF FINDINGS

1. Battelle forecasts that the total U.S. expenditures for R&D will be $155.2 billion during calendar year 1991. This is an increase of 3.4 percent over the $150 billion that the National Science Foundation (NSF) estimates actually will have been spent in 1990.

2. Costs of performing R&D are expected to rise approximately 2.4 percent from 1990 to a 1991 index level of 141.47 (1982 = 100 percent), absorbing a portion of the increased funding. However, this implies a *real* increase in expenditures of approximately 1.0 percent, reaching a new peak in total real funding of R&D (Figure 3).

3. Federal government funding in 1991 is expected to be about $72.2 billion (46.5 percent of total), an increase of $2.95 billion (4.3 percent) from 1990. Performance of R&D by the federal government will represent $17.5 billion (11.3 percent), an increase of $800 million (4.8 percent) over 1990 estimates.

4. Industrial funding in 1991 is expected to be nearly $75.9 billion (48.9 percent of total) representing an increase of $1.65 billion (2.2 percent) over that of 1990. Performance of R&D by industry is expected to rise to $111 billion (71.5 percent of total), an increase of $2.85 billion (2.6 percent over 1990).

5. Estimates of federal government versus industry support for the R&D performed by industry are included in the 1991 forecast. Drawing upon historical trends, the anticipated total performance by the industrial sector will be supported by the federal government in the amount of approximately 34 percent. This fraction of support has remained essentially constant over the past decade or so.

6. Academic and other nonprofit institutions taken together are expected to fund $7.1 billion of R&D in 1991 (4.6 percent of total) and to perform over $26.6 billion (about 17.1 percent). These figures represent increases in the percentage of support and performance over the 1990 NSF estimates. These figures also include the federal support to Federally Funded Research and Development Centers which are managed by individual universities or consortia.

7. Within the nonprofit category, colleges and universities are expected to account for 65.5 percent of the 1991 funding and 83.9 percent of the R&D performance. Both of these figures are comparable with the ratios derived from the 1990 NSF estimates.

8. Historically, the costs of R&D performance have risen steadily in all four categories (federal, industrial, colleges and universities, and other nonprofits), with the rate of increase being driven by overall inflation, a so-called "sophistication" factor, and the general nature of research programs.

9. The trends in real R&D effort (see Figure 3) continue to move upward, as they have over much of the past decade. Following a trend that has been forecast for the past three years, Battelle estimates that the real growth of R&D will continue to decline over the next few years, but that significant increases will again occur in the latter half of the decade.

10. Significant factors that appear to be influencing trends in the support and performance of R&D include:

(a) Federal government emphasis on defense programs will have a continued influence on total R&D support and the principal industrial performers. These emphases will be felt primarily in the aerospace, electronics, and communications industries, but the rate of growth is expected to show a continued decline and a possible turnaround under the Bush Administration.

(b) Energy-related R&D programs will continue to experience mixed federal support. Although some of the so-called "big science" programs have not had the level of continuing support that had been anticipated, early indications are that even these will find greater favor in 1991, and continuing into 1992.

(c) The university self-funded programs are likely to continue growth, although their rate of growth may not be sustained over the near term.

(d) The so-called "peace dividend," highly touted following the political, economic, and military changes in Eastern Europe, will not likely have a significant impact. The potential high costs associated with the Middle East, the pressures faced by the federal budget, and the concern over real business recession will temper the total rate of growth of R&D and, perhaps, even lead to a short-term downturn in real R&D expenditures.

11. As a continuing feature, this report provides a preliminary forecast of R&D funding levels in 1992. Indications are that total U.S. expenditures for R&D in 1992 will be $158.4 billion (uncorrected for inflation).

12. The types of statistics and surveys—even with their inherent inaccuracies—are sufficient for broad analyses of U.S. R&D trends; however, it is shown that much more detailed work will be required if R&D analyses are to be more useful for defining competitive postures, both for individual industries and for the nation as a whole.

ANALYSIS AND FORECAST

Since research and development (R&D)* and the applications of technology are our prime concerns, Battelle is interested both in forecasting R&D expenditures and in assessing the cumulative results of R&D activities—technological, economic, and social. Accordingly, Battelle has carried on a continuing study into the forces affecting R&D activities and sources of support. Among the tangible products of this research has been a series of annual analyses and forecasts of R&D expenditures. This report represents the latest in that series.

The content of this report has evolved over the years in an attempt to supply information Battelle considers useful to the R&D community, but not adequately supplied by two well-known and respected series of reports: the National Science Foundation's *National Patterns of Science and Technology Resources* and the DRI/McGraw-Hill *Annual Survey of Business Plans for R&D*.

In much earlier years, NSF *Patterns* was published during the first half of each year (usually in April) and had included a forecast of that same full year's R&D expenditures by source of funds and by performer. More recently, *Patterns* had contained both the preliminary data for the closing fiscal year and estimates for the two preceding years. Recently, the publication of *Patterns* has been delayed until late in the calendar year, and it contains better estimates of the R&D funding and performance for that same year.

Budget restraints and employment freezes at NSF have taken their toll on the *Patterns* report and the supporting activities throughout the NSF Division of Science Resource Studies. The effects of these cutbacks have been felt not only by continuing private-sector users of NSF data but also by policy makers and analysts within the federal government. Furthermore, these same budget cutbacks have prompted the possibility that *Patterns* will only be published on a biannual basis (although some of the data will be available), thus adding more complications for both private- and public-sector users of this valuable resource.

As an additional complication, NSF data have always had a degree of uncertainty, especially as they relate to recent years' histories. Each year, the NSF data on previous years (sometimes as far back as 10 years) have been subject to corrections. For example, some of the 1986 data reported in 1990 are different from the 1986 data that were published in 1989. These adjustments thus present problems in consistency between forecasts made in different years. The lack of background data and their interpretation can only have a negative impact on those agencies concerned with the strength of the U.S. R&D effort and the policy measures that need to be taken in order to ensure competitive postures.

The McGraw-Hill surveys (usually published at about the same time as the earlier issues of *Patterns*) had made forecasts—the 1989 Survey (published in June) made forecasts for 1989 and 1991—but are confined to the overall performance of broad industrial sectors, some of which are not well defined and delineated, and do not separate federal government from industrial funding. These surveys, coupled with the "R&D Scoreboard" published in midyear by *Business Week*, are instructive to the extent that they provide generalized patterns and trends. However, as will also be shown in later discussions (see the Section titled "The Need for Better Data"), they fall far short of providing a complete tool for detailed analysis, evaluation, or planning.

Since the issuance of the 1980 Forecast, we had included a forecast of industrial R&D expenditures according to broad industry class, along with the estimated distribution of those funds between industrial and federal sources. This added feature provided the background necessary for understanding the way federal policy can affect industrial innovation, spur industrial support of its own R&D efforts, and enhance the long-term international competitiveness of U.S. industry.

However, we have temporarily suspended the detail on industrially performed R&D. The absence of DRI's primary data collection activity has forced a change in the coverage; we expect that this void will be filled in the future.

Continuing the practice initiated in the 1984 Forecast, we present estimates which cover a two-year forecast to 1992.

Historical Trends in R&D Funding and Performance

Although the NSF data series began in 1953, we begin our analysis with 1960 data. Even that year represents ancient history so far as the forces currently affecting R&D are concerned. The NSF data from 1960 through 1990 are shown in Table 1.

In 1960, NSF surveys indicated that approximately 64.6 percent of all R&D-supportive funds were provided by the federal government, 33.4 percent were provided by industry, and 1 percent each came from the academic community and from other nonprofit organizations.

* The National Science Foundation's definitions of R&D are given in the Technical Appendix to this report.

Between then and the present, federal funding rose to 66.5 percent in 1964, slowly declined to 45.1 percent in 1984, and has risen slowly since that time.* Over that same period, industrial funding declined to 31.2 percent in 1964 and rose to 51.6 percent in 1984, with a small decline thereafter. Since 1964, the percentage of total funding by colleges and universities rose steadily to a value between 2.0 and 2.3 percent of total funding. This level of funding remained constant for over a decade and a half, and then suddenly since 1985 increased to 2.8 percent in recent years. Other nonprofit funding reached a high of approximately 1.6 percent of the total (in 1978) but has exhibited a slow decline in the past decade. The apparent growth in college and university funding is partially ascribable to the more detailed bookkeeping methods that are used to account for this sector's sources of funds.

Through 1982, trends showed a continued increase in industrial funding as a percent of total funding, with a corresponding decrease in the proportion of federal-sector funding. Over the past eight years, however, the relative contributions by industry and the federal government have remained essentially constant. This is largely due to significant increases in defense spending, industrial response to a healthier economy, and other initiatives (see the later discussions on the role of industry).

Although the federal government had been the major *source* of R&D funds from 1953 through 1979, industry became the dominant R&D funder over the period 1980–1990. Industry is by far the major *performer* of R&D. Federal performance of R&D rose from 12.8 percent in 1960 to 16.1 percent in 1972. It has been decreasing since that year and has fluctuated around the 11.5 percent mark since 1980. Industrial performance reached a high point of 79 percent in 1957 and drifted steadily downward to a low of 68.6 percent in the early 1970s. More recent trends suggest a slow increase in the proportion of industrial performance, which has risen to over 73 percent and has maintained nearly that share over the past eight years, albeit with slight recent declines.

While the academic community's performance varied between 6 and 8 percent before 1960, there has been a slow but steady increase in the percentage of R&D performed in this sector, with recent levels reaching 14 percent. This total includes the R&D performed at the university-managed Federally Funded Research and Development Centers (FFRDCs). Since the early 1980s, this sector's share of performance had been in slight decline, although there has been a reversal of this trend in the most recent six years. Such a reversal has resulted in part from industrial initiatives (see later). For most of the 1960–80 period, other nonprofit organizations increased their share of performance of R&D from 2 to about 3.6 percent of the total, again with recent declines in that share.

It should be noted that federal funding supports research performed by all sectors. Currently, almost one-fourth of federal R&D funding supports intramural R&D; slightly over one-half supports industry; a little more than one-fifth supports colleges and universities (through direct grants and contracts, as well as through the FFRDCs); and the rest, slightly less than 4 percent, supports other nonprofit organizations. Industry absorbs almost all of its own funding, either intramurally or by contracting with other industrial performers. Its contracts and grants to colleges and universities exceed those to other nonprofit institutions by nearly a factor of two. Other nonprofits finance both themselves and academic institutions about equally, while colleges and universities absorb all the funds they originate.

In Table 1 we summarize the latest NSF time series on the sources of R&D funding and the volumes of R&D performance. During the interval since 1960, total R&D dollars (not adjusted for inflation) have increased more than elevenfold. Federal funding has multiplied by a factor of 7.9 and federal performance has increased by a factor of almost 9.7. In terms of constant dollars, total R&D expenditures have increased by a factor of 2.3 from 1960 to 1989, and federal performance has increased by slightly over 36 percent.

Also noteworthy is the high ratio of academic performance to academic funding. In the later years of this period, colleges and universities have provided about one-sixth of the total support for their own R&D activity, with much of the remainder (about 90 percent) coming primarily from the federal government. In recent years, this ratio has tended to decrease, not only as a result of some reduction in selected federal programs but also because of an increase in academic funding. As suggested earlier, this latter is largely a "bookkeeping" artifact created by the manner in which university funds are ascribed to the universities, rather than to the ultimate original sources. More will be said about this in later sections of the Forecast.

Beginning in 1968, there was a distinct change in the rate of growth in R&D, triggered by a leveling in current-dollar federal funding. This phase of the recent past seems to have ended with 1971, when current-dollar expenditures resumed an accelerating growth trend more

* Note that NSF data for 1989 and 1990 are "estimated." However, comparisons among the series of *Patterns* reports reveal that adjustments are made on earlier years' figures, with some adjustments carrying back several years. Thus, many of our calculations that are dependent upon long-term figures will vary from one year to the next.

Table 1.
Sources of R&D Funds and Performers of R&D, United States, Calendar Years 1960–1990 (Millions of Current Dollars)

Year	Total R&D	Sources of Funds: Federal Gov't.	Industry	Colleges and Universities[b]	Other Nonprofit[c]	Performance[a]: Federal Gov't.	Industry	Colleges and Universities[b]	Other Nonprofit[c]
1960	13,523	8,738	4,516	149	120	1,726	10,509	1,006	282
1961	14,316	9,250	4,757	165	144	1,874	10,908	1,173	361
1962	15,394	9,911	5,123	185	175	2,098	11,464	1,374	458
1963	17,059	11,204	5,456	207	192	2,279	12,630	1,611	539
1964	18,854	12,537	5,887	235	195	2,838	13,512	1,904	600
1965	20,044	13,012	6,548	267	217	3,093	14,185	2,103	663
1966	21,846	13,968	7,328	304	246	3,220	15,548	2,345	733
1967	23,146	14,395	8,142	345	264	3,396	16,385	2,594	771
1968	24,605	14,928	9,005	390	282	3,494	17,429	2,868	814
1969	25,631	14,895	10,010	420	306	3,503	18,308	2,950	870
1970	26,134	14,892	10,444	461	337	4,079	18,067	3,072	916
1971	26,676	14,964	10,822	529	361	4,228	18,320	3,216	912
1972	28,477	15,808	11,710	574	385	4,590	19,552	3,383	952
1973	30,718	16,399	13,293	613	413	4,762	21,249	3,701	1,006
1974	32,864	16,850	14,878	677	459	4,911	22,887	3,888	1,178
1975	35,213	18,109	15,820	749	535	5,354	24,187	4,396	1,276
1976	39,018	19,914	17,694	810	600	5,769	26,997	4,876	1,376
1977	42,783	21,594	19,629	888	672	6,012	29,825	5,451	1,495
1978	48,129	23,876	22,450	1,037	766	6,811	33,304	6,342	1,672
1979	54,924	26,815	26,082	1,198	829	7,417	38,226	7,287	1,994
1980	62,583	29,453	30,914	1,316	900	7,632	44,505	8,296	2,150
1981	71,819	33,374	35,946	1,540	959	8,425	51,810	9,284	2,300
1982	80,001	36,574	40,694	1,719	1,014	9,141	58,650	9,785	2,425
1983	89,126	40,829	45,252	1,918	1,127	10,582	65,268	10,601	2,675
1984	101,116	45,635	52,203	2,091	1,187	11,572	74,800	11,744	3,000
1985	113,745	52,070	57,979	2,356	1,340	12,945	84,239	13,186	3,375
1986	119,863	54,629	61,074	2,772	1,388	13,535	88,179	14,799	3,350
1987	127,316	58,508	64,088	3,135	1,585	13,413	94,117	16,286	3,500
1988	135,231	62,136	67,855	3,437	1,803	14,281	99,422	17,953	3,575
1989	142,000	65,850	70,350	3,850	1,950	15,800	103,000	19,300	3,900
1990[d]	150,000	69,200	74,250	4,300	2,250	16,700	108,150	21,050	4,100

Source: National Science Foundation.
(a) The R&D performance of Associated Federally Funded Research & Development Centers (some administered by industry, some by colleges and universities, and some by other nonprofit organizations) has been combined with that of the administering institutions.
(b) As sources of funds, these include state and local government funding.
(c) All other nonprofit institutions.
(d) Preliminary estimates by NSF.

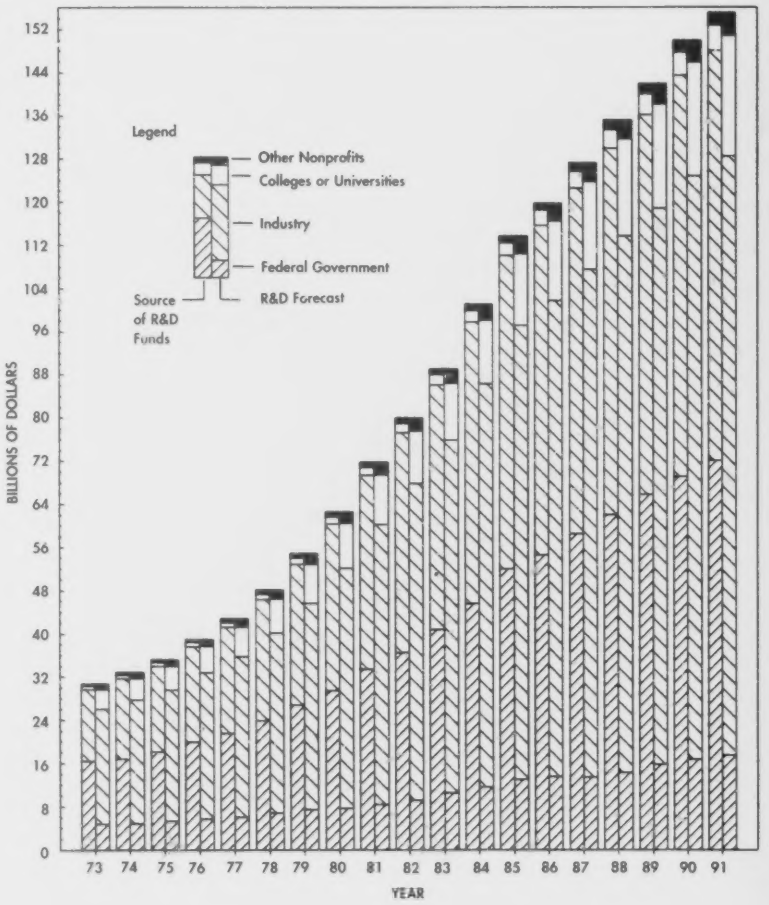
nearly like that before 1968. As anticipated in the last three years' Forecasts, there is a continued growth of total real R&D support, although the rate of growth has slowed. Present trends even suggest that the total real R&D support could go through a short-term reversal. Whether this will happen will depend upon a number of factors to be elaborated upon later in this report.

The continuing transition in the support and performance of R&D, to which we referred in earlier Forecasts, has had a significant impact on the patterns within the overall R&D enterprise. In addition to changes in energy and social service R&D programs, there have been changes in the structure of federally supported R&D. In particular, the budgets for basic research—much of which is directed ultimately toward defense applications—have shown a steady increase, growing at a rate of about 8 percent per year (in current dollars). However, the portion of federal R&D dollars directed toward truly basic research appears to have been declining in recent years.*

One must note, however, that the federal government's posture toward basic research—especially that associated with the so-called "big science" programs—has been expanding. In spite of the very significant costs associated with the Superconducting Supercollider, the Hubble telescope (and its potential repair and realignment), and the human genome programs, the Administration is taking a more positive attitude toward the support of basic research. Barring a major crisis, this support should not be seen as "soft" (platitudes and moral support without real hard cash) but should be viewed in terms of real, long-term commitment.

* One must use caution, however, in attempting to draw too many conclusions based upon the most readily available statistics. Two problems arise: (1) the demarcation between "basic research" and "applied research," as well as that between "applied research" and "development," is not uniformly applied; and (2) the actual detailed surveys are not sufficiently accurate, reproducible, or recent to provide much confidence in the details.

Figure 1.
R&D Funding and Performance by Sector, 1973–1991



The federal government will continue to move away from the support of research that is of a more applied and development work, especially where that is related to industrial applications where near-term commercialization is expected. On the other hand, support is expected to continue in "generic" technologies that have direct benefit to government and industry alike, such as in computer-aided design and manufacturing, the development of logistics-support software, and a continuing effort in high-risk basic research in the health-related fields.

Finally, the federal government will continue to support programs that deal with the environment—including the prevention, identification, and amelioration of threats to air, water, and land quality—and will promote other programs that contribute directly to economic growth.

Presently, the strongest federal action, as we shall see in later sections of this forecast and analysis, continues to be in areas of fundamental concern to the national government, as perceived by the Administration: (1) national defense; (2) technological competition from our trading partners; (3) health; and (4) the environment for economic growth. The extent to which federal actions can influence these areas will continue to be dependent upon a number of different factors, including the major developments in Eastern Europe, the decline in international tensions, and the pervasive question of the massive national debt.

Forecast for 1991

During calendar year 1991, Battelle expects the total current dollar volume of R&D activity to be higher than the 1990 level estimated by NSF. A comparison of Battelle's 1991 forecast with the last available NSF estimates for 1990 is shown in Table 2. The 1991 forecast is shown in its historical setting in Table 1 and Figure 1.

Referring to Table 2, we estimate the total calendar year 1991 R&D volume to be $155.2 billion, a 3.43 percent increase over the NSF estimates for 1990.* It is expected that part of this increase will be absorbed by continued inflation (which we estimate to be only 2.4 percent from 1990 to 1991 for R&D).

In connection with this forecast, several important factors must be recognized. First, the total current-dollar projected increase includes an inflation factor that depends primarily on the inflation rate as it applies to R&D alone. As will be noted in the discussion of the Cost of Research Index, this inflation factor is fundamentally different from that associated with the more familiar Consumer Price Index.

In addition, it is apparent that concerns over the federal debt have influenced the appropriations bills for the 1991 federal budget. Furthermore, since part of the calendar year 1991 will come during the next fiscal year (1992), the budget process throughout this current calendar year will have a continuing effect on total expenditures. Finally, industrial support for R&D will continue to be affected by previous years' sales and earnings, as well as concerns over an incipient recession, and should be expected to increase at only a small rate.

* These NSF estimates are presented here as reported in "National Patterns of R&D Resources: 1990," NSF Report 90–316, May, 1990.

Table 2.
Estimated R&D Expenditures by Source of Funds and by Performers, U.S. Calendar Years 1990 and 1991 (Millions of Current Dollars)

Source of Funds	Performer				Source Totals	
	Federal Government	Industry	Colleges and Universities	Other Nonprofit	Dollars	Percent of All Funds
1990 NSF ESTIMATES						
Federal Government	16,700	35,650	14,450	2,400	69,200	46.13
Industry	—	72,500	1,150	600	74,250	49.50
Colleges & Universities			4,300	—	4,300	2.87
Other Nonprofit	—	—	1,150	1,100	2,250	1.50
Performer Dollars	16,700	108,150	21,050	4,100	150,000	100
Totals Percent	11.13	72.10	14.03	2.73		
1991 BATTELLE FORECAST						
Federal Government	17,500	37,000	15,200	2,450	72,150	46.50
Industry	—	74,000	1,250	650	75,900	48.92
Colleges & Universities		—	4,650	—	4,650	3.00
Other Nonprofit	—	—	1,250	1,200	2,450	1.58
Performer Dollars	17,500	111,000	22,350	4,300	155,150	100
Totals Percent	11.28	71.54	14.41	2.77		
PERCENTAGE INCREASES OVER 1990 ESTIMATES						
Federal Government	4.79	3.79	5.19	2.08	4.26	
Industry	—	2.07	8.70	8.33	2.22	
Colleges & Universities	—	—	8.14	—	8.14	
Other Nonprofit	—	—	8.70	9.09	8.89	
Performer Dollars	4.79	2.64	6.18	4.88	3.43	

In using Table 2, the reader should keep clearly in mind all the distinctions made by the table headings. For instance, in the *column* headed "Industry," we see that the total amount of R&D expected to be performed by industry in 1991 will be $111 billion. Of this, $37 billion will be funded by federal agencies, and $74 billion by industry. On the other hand, the *row* headed "Industry" indicates that industrial sources of funds are expected to support about $75.9 billion of R&D. Of this, $74 billion will be performed by industry, slightly over $1 billion by colleges and universities, and $650 million by other nonprofit organizations. Included within the "Industry/Industry diagonal" element is the research and development that is supported by one industrial organization and performed by another.

Continued inflation is expected to characterize 1991, although the rate, as experienced in R&D, has been declining for the past few years. The NSF estimated that current dollar total R&D activity rose by 5.6 percent from 1989 to 1990. We project a smaller increase, 4.79 percent, from 1990 to 1991. As will be shown in connection with the Cost of R&D Index, not all of this increase is expected to be absorbed by inflation.

With respect to the *composition* of R&D activity, the expected pattern continues to be one of year-to-year stability or very slow change. Expected to provide the major impetus for change are defense-, science-, and technology-based problems; considerations of economic development and the federal budget deficit; and foreign competition. It is also important to note that the proportionate composition of both funding and performance will change very little. The federal government will account for 46.5 percent of the total funding, as compared with 48.9 percent from industry. Industry will account for almost three-fourths of total performance. These two distributions for 1991 are summarized in Figure 2.

The Role of Federal Agencies

Although federal funding of R&D has lagged behind that of industry since 1980, it is important to consider the federal role and R&D budgets as having major influences on total R&D spending. The federal role is important on three counts: (1) the government provides approximately 45 percent of the total funding; (2) government policies have an influence on industrial support of R&D; and (3) government policies have a strong influence on the interactions and cooperation between government and industry, as well as the interactions between other sectors.

The Federal Budget for Fiscal Year 1991, which began on October 1, 1990, bears more influence of the Bush Administration than it does of

the hold-over commitments of the previous Reagan years. There is a less strident tone as it relates to the roles that the federal government should take, less basic philosophy regarding the roles of the government, and a greater degree of imagination with respect to science and technology.

One should not infer that the so-called "Golden Days of R&D" experienced in the early 1960s will return in full; there are just too many other pressures on the Budget to permit massive infusions of funds for R&D, especially basic research. The huge deficits that derived from no-tax and military buildup initiatives and the bailouts of the financial institutions have created a vise within which there is little room for maneuvering. Added to this are increased expenses and reduced revenues associated with the situation in the Middle East, rising fuel prices, slowdowns in business, and a "real recession waiting to happen." Perhaps the rosiest picture that can be painted as it relates to the federal role in R&D is that there appears to be a greater sensitivity to the role that research plays in accomplishing the overall objectives of the nation: strong defense, a strong economy, and a strong environment within which the fruits of research can be applied.

Battelle projects that federal funding in calendar year 1991 will likely reach a level of $72.2 billion. This figure is based upon: (1) recent trends in federal budgeting, as reflected in NSF data series on R&D funding; (2) the relationship between federal funding and federal obligations; (3) the fact that three calendar quarters' funding will be determined by the FY 1991 appropriation; and (4) the modification of selected mission agency activities.*

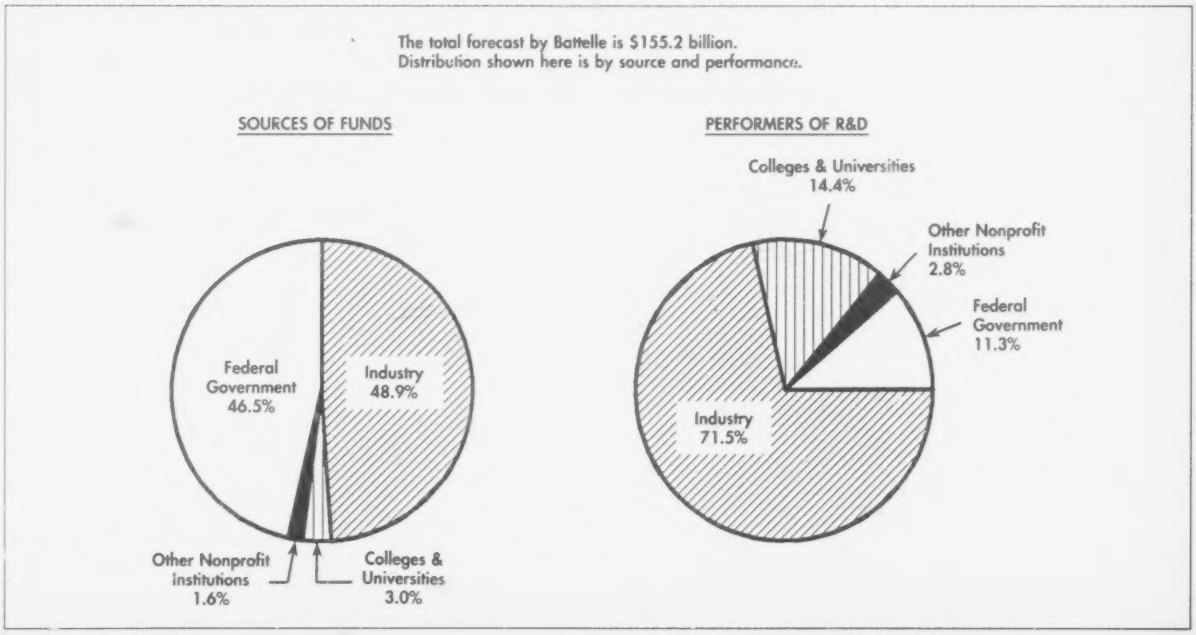
The R&D-Minded Agencies

The big-money agencies in terms of total 1991 federal R&D funding will include the Department of Defense (DoD), the Department of Health and Human Services (HHS), the National Aeronautics and Space Administration (NASA), and the Department of Energy (DOE). Among the smaller agencies, the important suppliers of funds for extramural R&D are the NSF, the Department of Agriculture (DOA), the Department of the Interior (DOI), the Environmental Protection Agency (EPA), the Department of Commerce (DOC), the Department of Transportation (DOT), the Agency for International Development (AID), and the Department of Veterans' Affairs (VA). Estimated percentage shares for conducting R&D in the early proposed budgets for FY 1991, and comparative estimates of the FY 1990 plans, are:

	Authority	
	1990	1991
DoD	58.43	56.82
HHS	13.35	13.11
NASA	10.02	12.35
DOE	9.45	8.89
NSF	2.77	2.91
DOA	1.74	1.74
DOI	0.79	0.72
EPA	0.68	0.68
DOC	0.67	0.65
DOT	0.53	0.62
AID	0.36	0.31
VA	0.34	0.29
Others	0.88	0.91

* This estimate applies only to spending for the *performance* of R&D, and does not include any spending for R&D *facilities*.

Figure 2.
R&D Expenditures in the U.S., Calendar Year 1991


The total forecast by Battelle is $155.2 billion.
Distribution shown here is by source and performance.
SOURCES OF FUNDS
Federal Government 46.5%
Industry 48.9%
Other Nonprofit institutions 1.6%
Colleges & Universities 3.0%
PERFORMERS OF R&D
Colleges & Universities 14.4%
Other Nonprofit Institutions 2.8%
Federal Government 11.3%
Industry 71.5%

It is obvious from this listing that DoD continues to dominate the federal scene, accounting single-handedly for over half of the R&D budget. The Big Four (DoD, HHS, NASA, and DOE) account for over 91 percent of anticipated federal R&D expenditures, although the distributions within these four have changed slightly over the recent past (and are expected to do so in the future). The next six largest R&D-supporting agencies account for only 7.3 percent, and all others combined account for approximately 1.5 percent.

A reading of the federal budget for R&D reveals that there is considerable support being given to the underpinning of science and technology that supports a broad range of both government and industrial needs. To be sure, one cannot always distinguish between these two users of research output, for they tend to go hand-in-hand; a more efficient, productive industry strengthens the ability of government to maintain revenue flows that support other necessary functions of government. Hence, federal initiatives cover a spectrum of needs and opportunities that includes advanced technologies in robotics, manufacturing technology, high performance computing, semiconductors, advanced imaging technologies, and superconductivity.

In addition, increases in this year's Budget are directed toward new technology for improved transportation systems, strengthening the science education systems, enhancing food production and safety, and an expanded effort to combat AIDS. And in the effort to expand the breadth of knowledge and understanding of the global and universal environment, the Budget provides increases in R&D associated with the Superconducting Supercollider, the enabling technology to support the space station and space exploration, and the broad field of biotechnology.

In viewing the estimated Budget authority for the different federal agencies, it is important to note that many agencies support research in areas which are not obviously connected with the agency's formal designation. For example, the Department of Energy budget includes R&D support that relates to clean use of fuels (environmental protection), nuclear energy (for both defense and for power generation), and reactor design and safety (materials research). Similarly, the Department of Defense continues to support R&D that is related to weapons and delivery systems, yet this also encompasses materials development (composites and high-temperature alloys), materials and systems distribution (logistics software and transportation/packaging systems), specialized food and clothing development, and education/training programs. And the National Science Foundation covers an array of technical fields that span the spectrum from understanding of the arctic environment to the development of new materials to high energy physics and biological processes.

The continued increase in defense-related R&D derives from the development and acquisition of more advanced major weapons systems and the Administration's commitment to highly sophisticated space-deployed defense approaches.

The Applications of Federally Supported R&D

The above brief discussion of federally supported R&D programs—partially enumerating the federal role in conducting research and supporting the other institutions that perform research—has emphasized the programs that have specific application to rather well-defined objectives. In large part, these programs are for the direct and indirect support of functions that are under the purview of the federal government, either because of their direct applications to functions that are specifically assigned to the government or because they represent research that is necessary but is too costly for other sources to support.

Over the past decade or more, various efforts have been forwarded to make even better use of the technology that has been supported and developed by the federal government, either in its own laboratories or in those of its contractors. Although the practice has been going on for many years, formalized efforts at "technology transfer" have been established for the major purpose of utilizing existing government-developed technologies in applications that are far different from those originally proposed. The passage of the Stevenson-Wydler Act and subsequent Technology Transfer Acts have laid the groundwork for initiatives that are being taken by the federal government, units of subfederal government, quasi-governmental agencies, and universities and private industry.

Specifically, state governments have looked toward the federal laboratories as a source of technology which, in modified form, could be implemented with the objectives of improving the productive capacity of existing industry, for creating new industry through "spin-off" activities, and for attracting new industries that would benefit from close liaison with existing federal laboratories. Local economic development districts and chambers of commerce have begun to formalize plans for developing communications and technology translation activities that could enhance the business climate in their jurisdictions, and could serve as the basis for new business activities.

Each of these initiatives has responded to the *opportunity* that is provided by the federal laboratory system, the *mandate* that has been directed toward these laboratories, and, in some cases, the political *necessity* of proving the non-mission-specific utility of the laboratory. Regardless of the driving forces behind the effort, the energies of all parties concerned—the federal laboratory technology source, the industry technology user, and the facilitating interfaces between them—will be marshalled to promote a greater economic development through the applications of technology.

The transfer process is not a simple one, for it faces a major dilemma in terms of "access." In this context, it does not merely mean the mere physical and intellectual access to the source of technology; it means awareness of technological progress at a time prior to the perfection of the technology. It means knowledge of the government objective and the means whereby it is being achieved, with sufficient knowledge of the technology such that it can be "diverted" toward individual applications and markets *before* it is sufficiently sophisticated to be useful in, say, a military application.

Much has been made of the concept of "second-use," where this refers to the application of a technology originally designed for one end and then finding another area in which it can be applied. In the context of technology transfer, it is perhaps more appropriate to identify "technology in progress" and capture the unsophisticated form for commercial application. In such cases, "second-use" actually refers to the ultimate objective of the original researcher, while "first-use" finds its way into commercial marketplaces.

Percentage of federal funding that goes to federal laboratories and to FFRDCs

Year	A	B	C
1980	25.9	7.6	33.5
1981	25.2	7.4	32.6
1982	25.0	6.8	31.8
1983	25.9	6.7	32.6
1984	25.4	6.9	32.3
1985	24.9	6.8	31.7
1986	24.8	7.1	31.9
1987	22.9	7.2	30.1
1988	23.0	7.3	30.3
1989	24.0	7.4	31.4
1990	24.1	7.6	31.7
1991	24.3	7.6	31.9

A = fed funding to fed labs
B = fed funding to FFRDCs
C = fed funding to fed labs + FFRDCs (C&U-operated)

The total R&D effort, one which will be pursued by federal, industrial, and intermediary institutions, will be one in which it is more appropriate to look at a fourth class of research; in addition to the traditional basic, applied, and development work, we expand the concept of "translational research"—a term first coined in the 1990 Battelle R&D Forecast. At one end of the spectrum, translational research will require the reverse engineering of finished products, the identification of applications of a technology where the requirements are not so stringent, and where simplified versions of the technology can be applied at far less cost. At the other end—and perhaps the easiest to undertake—translational research requires a knowledge of work in progress, the directions that it is taking, and the alternate applications that can be commercialized before advanced government applications are realized.

Pioneering steps have been taken to facilitate the government/industry interface, to lower the institutional barriers that exist, to provide incentives for researchers on both sides of the transfer process, to expedite licensing of technology, and to even make government facilities and personnel available for selected tasks. The process requires cooperation and a willingness to serve; it requires sensitivity to prime government mission responsibilities and to industrial decision-making processes; it requires imagination and an environment in which government and industrial applications specialists can communicate freely (within the constraints imposed by security and confidentiality); and it requires funding. The states of New Mexico, Maryland, Ohio, and others have taken initiatives to tap the federal resources and develop operations that will accelerate the commercialization of technology. It is expected that others will follow.

The opening up of the federal laboratories is not a panacea. It is a significant step in the right direction. The effort by state or local governments is not significantly different from other initiatives that they have taken, including seed funds for technology development, the fostering of industry/university liaisons, and the establishment of other incentives and institutions. Perhaps a coupling of needs and actions on the part of the various levels of government will provide the type of environment within which existing industry can improve and new industry can be developed.

The Role of Industry

NSF data indicate that during the period 1980–1990, industrial support of R&D was greater than federal support. Battelle projects that industrial funding in 1991 will again exceed federal funding. As has always been the case, industry will be by far the predominant R&D performer.

Table 3.
Sectoral Growth Rates in Funding and Performing R&D, 1981–1990

1981 = 100.0%

Sector	Source	Performer
Total United States	208.9	208.9
Federal Government	207.3	198.2
Industry	206.6	208.7
Colleges & Universities	279.2	226.7
Other Nonprofit	234.6	178.3

Source: Derived from Table 1.

For 1990, the NSF has estimated that industry provided 49.5 percent of total funding and performed over 72 percent of all R&D work (see Table 2). Battelle's forecast for 1991 changes these shares almost imperceptibly to nearly 48.9 and 71.5 percent, respectively.

The NSF data base indicates that industry has been the second fastest-growing sector. Table 3 compares sectoral growth rates for the nine-year interval 1981–1990. It is of particular interest that, as a source of funds, colleges and universities have grown quite significantly. The rapid increase in university funding relates to the manner in which R&D statistics are collected and accounted for.

Battelle projects considerable differences among the 1990–91 sectoral growth rates. Total R&D expenditures are expected to grow by 3.43 percent; industrial funding and performance are expected to increase by 2.2 and 2.6 percent, respectively.

Industrial funding is expected to rise from an NSF estimated level of almost $74.3 billion in 1990 to $75.9 billion in 1991. Industrial performance will rise from $108.2 billion to $111 billion. Note that the increases in both funding and performance by industry are smaller than in previous years, as had been anticipated in the 1990 Battelle forecast.

Industrial research, as it applies to the accomplishment of industrial and governmental objectives, is both a means to an end and an end in itself. While the continuing profit motive in a competitive marketplace spurs R&D for individual industry's benefit, so also does the industrial system provide a mechanism for the execution of programs of high national priority.

The total R&D performed by industry can be divided into two major classifications: that which is supported by industry itself (either in its own laboratories or by contracts with other industrial laboratories) and that which is supported by the federal government. In previous years, the Battelle Forecast has included a breakdown of the total R&D expected to be performed in each of 17 broad sectors and an estimate of the split between industrial and government funding of that research. This feature has been temporarily suspended for the 1991 Forecast but may be reinstated in the future. In part, this is due to curtailment of the DRI/McGraw-Hill surveys, which served as an important data source for this analysis.

Even if the data were available, the distribution between federal and industrial funds can be somewhat misleading, because it does not address the more critical question of support for R&D among different lines of business. With R&D expenditures grouped according to major Standard Industrial Classification (SIC) codes, it is not possible to distinguish, for example, electronics research performed by a well-known electronics company from that performed by a subsidiary of a major company whose principal product line (and SIC code) falls into an entirely different category. Conversely, this determination does not isolate, for example, research in chemicals which is performed within the rubber or petroleum industries.

More specific information on the R&D expenditures within industry is extremely difficult to collect and assess, especially in those cases where (1) individual companies are engaged in a variety of research programs to support different lines of business, or (2) companies' R&D is diversified among an array of products and processes within the same line of business.

The extension to the case where both industrial and federal moneys are involved is similarly difficult. Detailed data are available relative to government support of R&D by industry and by area of research. However, the comparison with expenditures of industries' own funds cannot be pursued without dissecting specific industrial R&D budgets.

These latter are, of course, almost always considered as confidential and proprietary information. Over the past few years, Battelle programs have been directed toward analyzing R&D within broad industrial classes, and thereby providing specialized information which assists in the R&D planning, management, and assessment activities of the cooperating industries. It will be quite some time, however, before sufficient detail is collected for a large number of R&D-intensive industries, and for a more nearly accurate picture of the government/industry split—with all its implications—to emerge. More will be said of this in the section on The Need for Better Data.

An additional caveat should be noted relative to the ready availability of R&D data. A most convenient source of data on R&D investment is the annual *Business Week* Scoreboard, usually published near the middle of the calendar year. The Scoreboard provides compilations of total R&D data for the major publicly held corporations, along with associated trends and ratios. While these data lend insights into broad patterns of

support, they do not include information on privately held and/or small businesses. It is generally held that these latter firms represent a most important element in the areas of applied research, commercialization, and new-job information.

In spite of the uncertainties that attend the actual numbers that are reported or projected, it is important to emphasize that the *trends* in R&D performance and the factors that influence these trends are more important than the more accurate figures.

The performance of R&D by industry will be financed either by the federal government or by industry itself (Table 2). Industrially funded work will be done primarily either internally or contracted out to other industries. A very small amount (approximately 2.5 percent) will be done extramurally by universities and other nonprofit institutions. Overall, two-thirds of industrially performed R&D will be funded by industry, with the remainder being supported by the federal government.

Factors Affecting Future Industrial Support

Over the past few years, industrial spending on R&D has increased significantly, although, as anticipated in recent years' Forecasts, the rate of increase in 1991 will be slightly lower. Spurts in industrial support, especially in the early and mid-1980s, had been the result of a healthier economy, increased sales and profits (both early indicators of R&D fund availability), relaxation of perceived barriers to cooperative research, and—to a small degree—the R&D tax credit enacted in 1981. However, other factors have influenced the near-future support for R&D. Several aspects of these factors must be emphasized, especially if we are to appreciate the lessons of history and plans for the future.

Industry is not driven solely by technology and its availability, nor should it be. The U.S. R&D enterprise has, over the past 30 years and more, provided an incalculable wealth of understanding, a veritable flood of knowledge related to the properties of materials and the devices and systems that can be developed from them. Almost every sector of the economy has developed a backlog of information and know-how that can continuously enhance all manner of processes and products. It is well within our grasp to improve health care; to access, process, and utilize growing volumes of information; to implement processes and products that would in the long run save all manner of resources, to improve the capacity for growing, processing, and distributing food products; to reduce pollution and take advantage of waste; and to bolster the overall physical infrastructure.

But the availability of technology and the fruits of R&D do not determine the extent to which technology is applied. The use of new technology can carry significant cost—including the direct cost of acquiring know-how, and the unamortized costs of in-place processes. The ultimate resolution then comes down to a series of alternatives and considerations: to adapt or not; the cost of innovating as contrasted with the cost of *not* innovating; and the issue of potential short-term losses vs. long-term profitability or even survival.

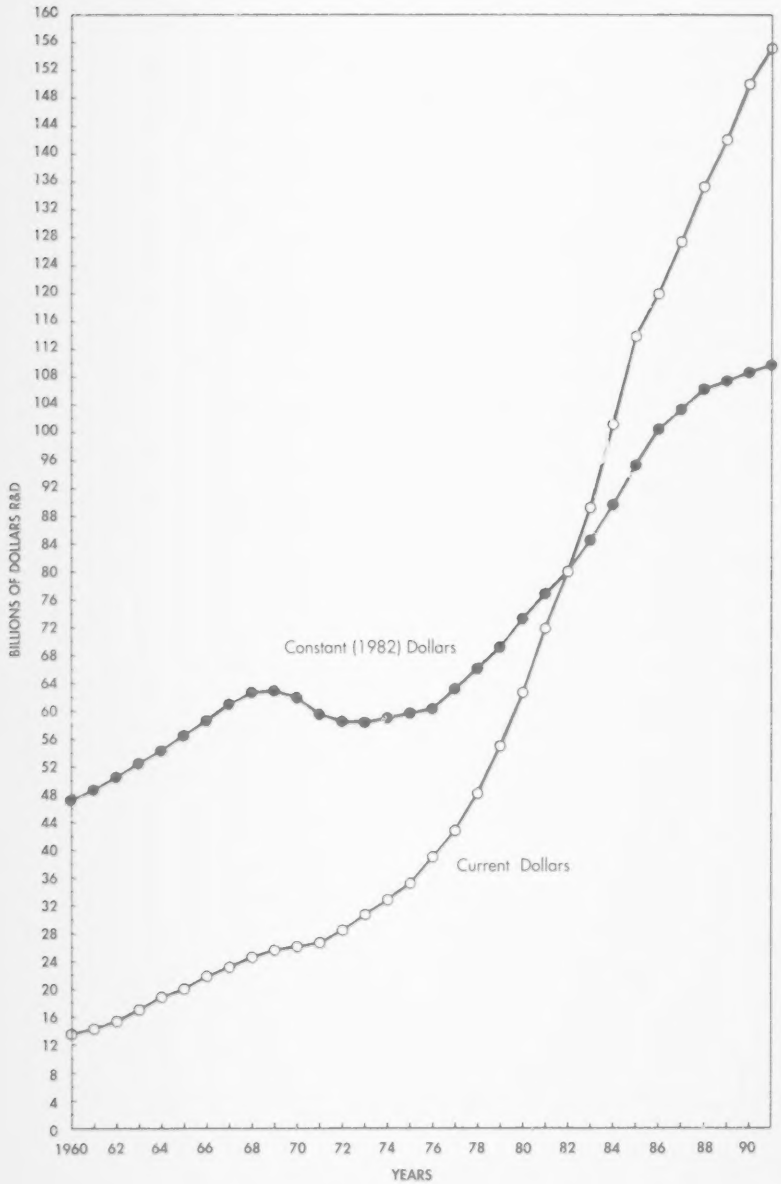
With this background, we note several points that have had an impact on recent industrial support of R&D and which are expected to affect the near-term future support.

The philosophical cheerleading which emphasized "reindustrialization" and "competitiveness" may have driven selected firms to make the necessary investments to modernize operations and increase productivity. But other forces have had their influences on industrial R&D expenditures. Specifically, the commitment to long-term growth and strength has been affected by significant return to the short-term outlook that pervaded industrial management only a few years ago. The concepts of research and innovation are basically incompatible with the near-term profit objective. Thus, much effort has been directed toward alternative means of achieving this end, namely, the continued restructuring, buying of companies, and selling of non-revenue-producing components, and "the art of the deal." Manipulation, rather than innovation, has become the route to selective success.

The merger and acquisition practice has had some impact on R&D funding, and this is manifest in at least three ways: (1) the reduction or elimination of R&D spending and facilities, while aiming for short-term profit; (2) the use of resources to pay off debt incurred by acquisition; and (3) the reduction of duplicate operations in intra-industry mergers. The last factor represents a reduction in total funding without a significant loss of technology-development potential. The first two are obviously detrimental to technical growth.

For the past three years, this Forecast has expected a slowdown in the rate of growth of R&D expenditures, perhaps even resulting in *decreases* in the constant dollar support of R&D. Such decreases certainly would not be unprecedented, there having been a similar reduction in the early and mid-1970s (see Figure 3). If such a turnaround were to come, it would probably not last long; barring unforeseen major dislocations in the economy, a renewed perception of a federal government that is both "friendly" to business and understanding of the role of research will mostly reinstate confidence and the resultant support to R&D.

Figure 3.
Total R&D Expenditures, 1960–1991, in Current Dollars and Constant Dollars (1982 = 100%)



Even without specific numbers that would reflect the amounts of R&D expected in individual sectors, there are several points that can be made that will shed some light on expected trends. Even as this is being written, there are concerns about whether the country is in a recession, whether it is a recession waiting to happen, or if it is merely a pause in economic growth. To be sure, there are a number of factors that are causing uncertainties in most businesses, not the least of which are concerns over energy costs and availability and the actions to be taken relative to the federal deficit.

According to the reviews of *Business Week*, industrial output is generally down although not as badly as was the case early in the 1980s. Defense industries (particularly aerospace) are concerned that costs associated with increases in Middle East expenditures will come out of new procurements and the associated new R&D. But expanded sales for the replenishing of supplies and new orders for Saudi Arabia arms are coming along. To be sure, some weapons systems have been cancelled, and this could mean fewer R&D dollars that can be spent. In addition, disarmament talks and the relaxation of tensions relative to the Soviet Bloc (which does not really exist at this time) will result in cutbacks in nuclear weapons, both in production and in R&D.

Alternatively, civil aircraft orders have not been dramatically affected, and, while the direct R&D requirements may not be significant, the tooling requirements will be great in order to keep up with the demand. Thus, the machinery sectors may do well in terms of sales and the pursuit of R&D activities that lead to the upgrading of manufacturing facilities. In addition, a continuing pressure is being maintained to develop improved CAD/CAM classes of equipment and systems, with the objectives of reducing manufacturing costs and running "batches of one" for rapid prototyping.

Continued efforts will be directed toward higher efficiency aircraft research, particularly as the commercial airlines retire older carriers and opt for new designs and characteristics that will reduce operating costs.

Profits have been increasing in the chemicals industries, but so are costs, especially those that relate to petroleum as a feedstock. In order to maintain profits, the "expendable" costs—such as R&D—might suffer. In addition, much effort has to be directed toward preventing or ameliorating adverse environmental effects, and these again are costs that do not show a product that gives a

direct market. Overall R&D in this industry is expected to rise a little, but not as fast as sales or earnings. In contrast, the pharmaceuticals subset of the chemicals industry has been showing a strong increase in R&D effort, and this trend is expected to continue.

The telecommunications industry is still a growth business, with falling prices and higher demand. Satellite communications, cellular phone systems, video-conferencing networking, and the like are pushing the telecommunications business. In this industry there is a mix of doing R&D and merely defining markets to which others will provide the R&D to carry them through. As the demographics of the workforce change, there will likely be a greater demand for simpler-use telecommunications, greater demand for workers not in the workplace but still working, and more in the way of transportation-substitute technologies. The "electric cottage," long thought to be a major force looming just over the horizon and often dispelled because of the socialization needs of people, can be coming closer to reality. The R&D that leads toward more convenient and more portable communications devices and systems will continue to aim for this market.

Great efforts on semiconductor R&D will look to more effective chips for all manner of computers, and there is an indication that much of the chip-related research will be directed toward the area of "retrofitting" of old systems with new speed and capacity.

The Impacts of Technological Advance

In other sections of this forecast, we have spoken of the fact that the U.S. R&D enterprise does not lack for the capacity to innovate, to discover, to improve, and to design new approaches toward the development of new products and processes. The argument has been raised that the U.S. lags behind other countries in terms of their expenditures on R&D as a percent of GNP, and therefore we will "fall behind." It has further been maintained that U.S. industry is categorically more concerned with short-term profits than with long-term stability or survivability. And finally it has been noted that while we have significant strength in R&D capability in almost every area of science and technology, we lack either the will or the way to reduce R&D to practice.

Throughout this series of Annual Forecasts, as well as other activities, Battelle has examined many of these issues and has learned, as many others have, that technologically sound innovations cannot be considered alone in the decision to implement technology. One must face not only the costs of implementation and the cost of *status quo*, but also consider the broad question of the impacts of innovation and implementation. These impacts may be felt within a single organization or within both a local and national economy.

It is thus incumbent upon industry and government alike to delve more deeply into the issues of technology assessment and impact, addressing such questions as the effects of materials or process substitution; the "ripple factor" as technical advances in one sector have economic impacts in others; the needs for changes in the workforce; and the long-term planning that is required to accommodate requirements for scientists, managers, technicians, and other support personnel. Technology-based industry is perhaps more vulnerable to manpower issues that most other sectors, for the elements of intensive and extensive training and education lie at the core of a rapidly changing industrial base. As a consequence, these industries have a considerable stake in education at all levels and in the support of programs that will eventually provide them with much of their feedstock.

The call for greater consideration of the impacts of technological change does not mean to infer that all potential problems should be examined before new research is put to practice; to do so would stifle growth, would impair competitiveness, and would have a detrimental effect on research itself. But to encourage a greater awareness of the (positive and negative) impacts of technical change will better prepare users of new technology in the adoption and implementation of technology and strengthen the capacity to ward off any adverse effects.

The Role of Academic and Other Nonprofit Institutions

Nonprofit institutions—colleges, universities, and other types—both fund their own research and conduct research funded by federal agencies and/or industrial firms. It is generally conceded that a significant portion of all basic research, as well as some of the longer-maturing applied research, is conducted in this sector.

In 1960, the academic and other nonprofit institutions financed from their own resources (including endowments and direct state and local funds) approximately 2 percent of all R&D (see Table 1), while actually performing over 9.5 percent of the total. For 1991, Battelle forecasts that these same nonprofits will provide nearly 4.6 percent of all funding and will perform almost 17.2 percent of the total (see Table 2). These percentages are slightly higher than the corresponding ratios for the 1990 NSF estimates.

The growth in nonprofit R&D performance has been accompanied by minor shifting within the nonprofit sector. In 1960, the academic community accounted for 55.4 percent of total nonprofit funding and performed 78.1 percent of the nonprofit total. For 1991, Battelle forecasts

65.5 percent and 83.9 percent, respectively. A significant portion of the increase in academic support and performance derives from the increase in major industrial support ("directed endowments") associated with specialized areas of research such as electronics, artificial intelligence, and biological sciences.

There are two distinct groups of "other" nonprofit organizations. These are the foundations and associations which exist for various charitable and other purposes, and the nonprofit research centers which may or may not perform under contract. The first group funds a great deal of research, through grants and contracts. These go both to members of the academic community and to other nonprofit centers. The second group acts in three ways: (1) a member may perform as a foundation; (2) it may fund its own research performance; and/or (3) it may perform under contracts (with government, industry, or other nonprofits).

From 1965 to 1980 other nonprofit performance has fluctuated slightly between 3.3 and 3.7 percent of total R&D. Since then, this sector has declined to less than 3 percent. For 1991, Battelle estimates that the other nonprofit sector will comprise 2.77 percent of total R&D performance. Furthermore, we estimate that 51 percent of other nonprofit funding will go to colleges and universities, with the remaining 49 percent being spent by the other nonprofit sector itself. Following a decline in the 1976–1982 period, the percentage of support to colleges and universities is slightly higher than in recent years.*

The total R&D performance in the other nonprofit sectors is not increasing as rapidly as in other performing sectors. However, as noted above, this sector is composed of quite diverse constituent organizations. As performers of R&D, the establishments within this sector range from institutions such as Battelle (engaged in a spectrum of technology development, commercialization, and management programs) to small nonprofit firms that act as delivery mechanisms and research arms for federal, state, or local government agencies, especially for social programs. The activities of these latter types of organizations have been significantly reduced in recent years. As might be expected, the extent to which agencies support research is roughly related to the magnitude of their operational programs.

With large proportional decreases in, for example, federal funding of social programs, the concomitant decrease in research related to these programs has been felt by many nonprofit research organizations. Hence, it is not unexpected that the aggregate of nonprofit performers should display smaller-than-average growth rates, or, in fact, real declines in comparison with other performing sectors.

Finally, in addition to contracts or grants to support research on industrial problems (the "industry funding of colleges and universities" shown in Table 2), there is another form of support, not yet reported in detail by the NSF, that must be noted. This is the individual or collective industry/university arrangement which takes a form that more nearly resembles "directed endowments" than either a specific research contract or a general gift. The large multiyear programmatic grants are then accounted for as college and university self-funding.

R&D in the nonprofit sectors—particularly the colleges and universities—has been one of the mainstays of the growth of that basic knowledge that had led to the development of the total economy. In both public and private institutions, R&D has served both to expand understanding of science and technology and to play a critical role in the education process itself. Unfortunately, there is no totally reliable estimate of the amount of R&D that is actually conducted, or the relationship between the funding agencies and the performing institutions. Thus, one cannot develop reliable rationales or policies that relate to academic research, its support, and its important role in further advancing the objectives of an industrialized, technology-based society. As greater emphasis is placed on the issues of competitiveness and the most efficient use of total technical resources, a greater effort should be directed toward understanding the role that university research plays in the national economy and the incentives and barriers that influence utilization of this resource.

The Cost of R&D Inputs

From an economic point of view, inflation can be defined as a general rise in the price of goods and services that is not offset by corresponding increases in quality. If the prices of everything tend to rise together, slowly and in the same proportions, and if individual incomes also rise in those same proportions, the relationship between money and goods/services changes in a fashion that is detrimental mainly to the holders of such fixed-dollar obligations as life insurance. On the other hand, when the prices of things bought with income rise faster than the incomes, structural imbalances occur that may be quite painful to particular sectors of the economy.

* We must be cautious in drawing conclusions from the available data on R&D in the university and other nonprofit sectors. The primary survey data from which we work have not been collected directly and in great detail for a number of years. The NSF data are fairly good estimates, but small differences can give rise to significant percentage errors.

Goods Versus Services

Most considerations of prices tend to take place within the context of goods' prices (i.e., the prices of tangible things). The tangibility of goods makes it possible both to measure the quantity of their output and to estimate, within reasonable limits, changes in their quality. Thus, with respect to goods, there usually is agreement as to whether or not costs are rising faster than output, or prices faster than quality. That is to say, we tend to have general agreement that inflation is or is not occurring in the goods-related economy.

Services, on the other hand, are intangible. Therefore, we usually have greater difficulty achieving agreement that, in terms of any meaningful measure, the quantity or quality of service output is rising or falling. Thus, our only measure of many types of service output is the total amount of money that we pay for them—and that is a function of price and quantity, with no account taken of quality.

R&D, by definition a part of the "knowledge industry," is primarily a service activity, despite the fact that much of it ultimately becomes embodied in products. For this reason, we have no agreement as to what can be termed a "unit" of R&D output. Therefore, we cannot ascertain whether or not the "price" of R&D output is rising or falling. However, we can put a price on R&D inputs. For that reason, most discussions of the cost of R&D tend to be couched in those terms. Battelle has not yet given up hope of achieving a measurement of R&D output and from time to time has undertaken investigations that may lead to quantifying at least some kinds of R&D output. Nevertheless, such a measurement is not now available, and the discussion that follows must be in terms of input costs.

In viewing the costs of R&D performance, it is tempting to contrast the "inflation" in R&D with the commonly used Consumer Price Index—the factor that provides a measure of general inflation—or to use the Gross National Product (GNP) deflator, as NSF does. To do so misses three basic points distinguishing R&D from the more general set of purchases. First, the CPI is based upon a defined average "marketbasket" purchased for general consumption, and the GNP deflator covers a somewhat broader range. However, purchases by R&D performers are from a much more specialized collection of goods and services.

Second, the education of scientists and engineers has a built-in bias for the acquisition and use of more sophisticated (and, hence, generally more expensive) materials, devices, and systems required for the conduct of research. Were it not for this factor of the research culture, technological advancement would not be so rapid.

Third, and perhaps most important, the very nature of research is such that the problems addressed by researchers are increasingly more difficult. The easy questions are always answered first, and the effort necessary to make incremental gains in the understanding and application of science and technology is ever increasing. Thus, we generally expect that the "inflation rate," as applied to the conduct of R&D, will increase more rapidly than that of the average consumer purchases.

The Cost of Research Index does not *always* exceed the GNP deflator or the Consumer Price Index. While it is based upon the average weighted expenditures of R&D dollars per R&D professional, one must note that the actual dollars support a broad range of technical support personnel, computer hardware and software acquisition and use, amortization of equipment, and all the overheads associated with the conduct of research. Thus, the Index is also related to the sophistication of support equipment and the total environment of the research laboratory. Furthermore, there is an expected difference in the Index as it is interpreted for basic and applied research, and for development. To date, no effort has been directed toward analyzing the distinction between these broad fields of research, and no detailed methodology has yet been devised for investigating the true costs of research in greater detail.

The 'Cost of R&D Input' Index

In the absence of a measure of R&D output costs, many organizations, including the NSF, use the GNP deflator (from the national income and product accounts) as an indicator of changes in R&D costs. This index responds to the costs of both goods and services. R&D costs are made up primarily of service costs. Battelle researchers, therefore, feel that the GNP deflators probably have misstated rates of inflation with respect to R&D.

Several attempts have been made to determine the input mixes of typical R&D activities and to price each input, thereby generating standard weighted price indexes for R&D. To date, this approach has not been very productive, although such efforts continue and may eventually achieve success.

A pioneering effort to more directly measure trends and fluctuations in the cost of R&D was made by Helen Milton beginning in 1966.* Using information supplied by representative R&D performers, Milton compiled data on the total dollar cost of R&D per technical (professional) man-year.** Her series of cost indexes ended with 1970, using 1950 as the base year. Between 1970 and 1979

* See Helen C. Milton, "Cost of Research Index, 1920–1970." *Operations Research*, 20, 1–18 (1972).

** Milton said that "The 'technical man' is the professional scientist or engineer, plus his support."

Table 4.
Battelle Cost of Research Index* by Performing Sectors, Calendar Years 1960–1991 (1982 = 100)

Year	Total U.S.	Performing Sectors			
		Federal Government	Industry	Colleges & Universities	Other Nonprofit
1960	28.68	23.03	30.97	20.46	35.28
1961	29.43	24.07	31.32	23.30	36.21
1962	30.48	25.64	31.99	26.07	37.50
1963	32.51	26.48	34.29	28.94	37.04
1964	34.75	31.57	35.81	32.27	36.50
1965	35.52	32.85	36.47	33.15	37.09
1966	37.30	33.02	38.69	34.66	39.24
1967	37.98	33.52	39.35	35.84	39.93
1968	39.28	33.68	40.88	38.02	39.07
1969	40.76	34.58	42.53	37.78	45.69
1970	42.20	39.67	43.09	39.29	48.11
1971	44.82	43.43	45.77	41.19	47.01
1972	48.70	49.07	49.48	44.22	48.62
1973	52.66	53.71	53.04	50.05	50.23
1974	55.75	55.29	56.68	51.15	56.29
1975	59.02	60.18	59.54	54.45	61.77
1976	64.73	71.04	64.73	58.47	65.19
1977	67.77	71.75	67.88	62.99	69.36
1978	72.85	78.29	72.03	71.42	74.46
1979	79.48	84.82	78.31	80.28	80.73
1980	85.49	85.49	84.97	87.97	87.05
1981	93.52	93.41	93.05	96.04	94.85
1982	100.00	100.00	100.00	100.00	100.00
1983	105.51	113.31	103.94	107.37	108.30
1984	112.88	122.31	111.07	115.49	115.18
1985	119.43	135.09	116.67	123.58	121.22
1986	119.37	140.35	115.45	127.53	120.32
1987	123.33	141.32	119.93	130.91	123.71
1988	127.39	142.46	124.25	135.13	126.36
1989	132.28	155.95	127.94	139.19	136.98
1990	138.17	162.88	133.52	145.61	143.55
1991	141.47	168.92	136.21	149.52	149.61

Source: Estimated by Battelle from NSF and Battelle data.
*Costs of performing R&D per scientist/engineer (full-time equivalence).

Battelle extended the Milton Index Series by means of annual estimates. Finally, a new series of R&D cost indexes was introduced in the 1980 Battelle Forecast and Analysis. This new series, while conceptually similar to the Milton Series, is based upon a different body of data and does not show precisely the same year-to-year changes as the Milton Series and our earlier extensions of it.

The Battelle Cost of Research Index, displayed in Table 4, is based upon two series regularly published by the NSF: (1) the R&D performance figures, by sectors, that have already been discussed in connection with the Source/Performer Matrix (Table 2); and (2) estimates of the full-time equivalent numbers of R&D scientists and engineers employed by each performing sector. The ratio of costs to scientists/engineers for each sector provides the basis for the sectoral subseries, which are then weighted and combined into the all-sector average.

As derived from Table 4, Battelle's best estimates of recent increases in the total index are 3.8 percent for 1988–89, and 4.5 percent for 1989–90. We expect the cost of R&D to increase by about 2.4 percent between the estimated 1990 level (138.17) and the forecast level for 1991 (141.47) with the estimates stated in terms of the 1982 base.

Sector Comparisons of R&D Costs

During the interval 1982–91, costs of all R&D, as an average, are estimated to have risen by 41.5 percent. Increases in the individual performing sectors are expected to be: federal government, 68.9 percent; industry, 36.2 percent; colleges and universities, 49.5 percent; and other nonprofit, 49.6 percent. As noted, the 1990–91 cost increase for all R&D is estimated to be 2.4 percent. By sectors, the increases are estimated as federal, 3.71 percent; industry, 2.02 percent; colleges and universities, 2.68 percent; and other nonprofits, 4.22 percent.*

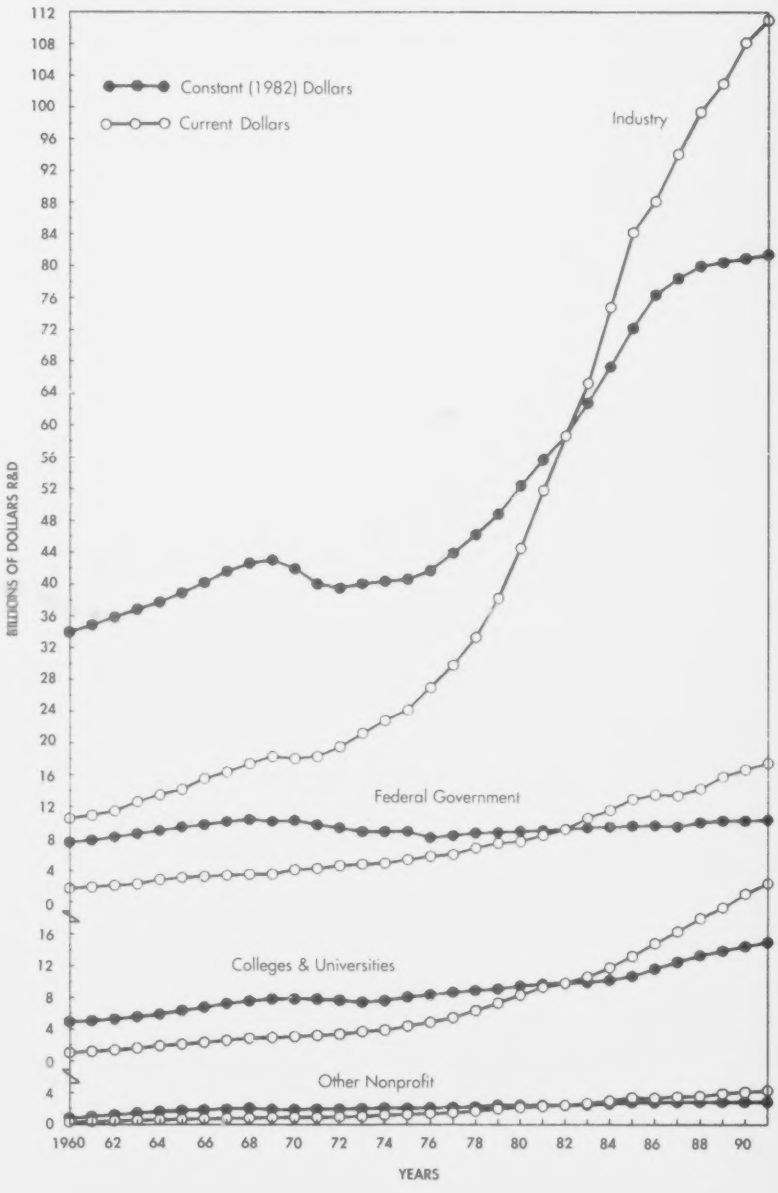
Trends in Real R&D Effort, by Sectors

If we take total expenditures and sector performance figures from Tables 1 and 2 and deflate them to constant 1982 dollars with the corresponding index numbers from Table 4, we can make parallel comparisons for each of the four performing sectors. These are shown in Table 5 and graphed in Figures 3 and 4.

In current (undeflated) dollars, total U.S. R&D expenditures have risen in every year of the period, even though the rate of increase fell sharply between 1969 and 1971. But the deflated (real effort) series before 1978 reached its peak in 1969, declined between 1969 and 1973, and moved generally sideways until 1977, when it exceeded $62 billion for the first time in eight years. We expect real R&D effort in 1991 to increase by 1.02 percent over 1990 and to reach a level that is 74.4 percent above its 1969 peak.

* The estimates of the Cost of Research Index and its year-to-year change are quite sensitive to changes in the basic data on expenditures and employment levels. Much of the input data are derived from NSF resources, which, as noted earlier, are adjusted annually.

Figure 4.
R&D Expenditures by Sectors, 1960–1991, in Current Dollars and Constant Dollars (1982 = 100%)



When we shift our attention to the performing sectors, we find that the recent upward drift of real R&D activity results from the behavior of the private sectors. The downturn or flat behavior in real expenditures that began after 1968–69 is clearly reflected by every sector. However, deviations in sector behavior emerged later, especially since about 1975. In government, the real performance series has recovered only slowly from its 1976 minimum and has not yet equaled its 1968 peak.

In the private sectors, industry reached its real low in 1972 and has since risen by 106 percent to its highest recorded value. The academic community reached a low in 1973. Since then, its real performance has risen by 102 percent and now stands well above the 1968 value. Other nonprofit institutions' real performance declined slightly from 1968 through 1970. Since that time, it has risen by 50.9 percent.

Finally, we turn to the data of Table 5 and the curves of Figures 3 and 4 to see the dramatic differences in the R&D trends among the four performing sectors. Since the lull of the early 1970s, industrial performance, funded by both government and industry, has been largely responsible for the real growth within the R&D enterprise. Using the same performance deflators as applied to the sources of funds, over the past decade, industrial support of R&D has increased at an average compounded rate of 3.88 percent per year , while federal support has increased at 1.8 percent per year on average.

The behavior exhibited in Figures 3 and 4 suggests that the real growth in R&D (and the economic development and expansion that result from it) has come from the applied research supported and performed by private industry. However, one cannot overlook the fact that such applied research and development must rest on, and evolve from, the basic research foundation—an activity that is primarily supported by the federal government (almost 65 percent).

Over the past few years, federal support has tended to shift more toward "development" and less toward basic and applied "research."* The federal government is still the major supporter of basic research, and trends in the federal budget indicate that this support will continue to be strong. In addition, there is a continuation of basic research support by industry. Yet, the volatility of those indicators (sales, profits, cash flow) that influence industrial R&D budgets precludes the stability needed for long-term planning.

* One must be careful not to read too much into the data that are available regarding the divisions among basic and applied research, and development. It is at times difficult to make the distinction as to where one phase stops and the next takes over. Furthermore, the definition as applied by the supporter may be substantially different from that applied by the performer.

Table 5.
Current and Constant Dollar (1982 = 100) R&D Expenditures in the U.S., 1960–1991, by Performers (All Amounts in Millions of Dollars)

	Total U.S.		Federal Government		Industry		Colleges and Universities		Other Nonprofits	
Year	Current	Constant	Current	Constant	Current	Constant	Current	Constant	Current	Constant
1960	13,523	47,147	1,726	7,496	10,509	33,935	1,006	4,917	282	799
1961	14,316	48,645	1,874	7,785	10,908	34,828	1,173	5,035	361	997
1962	15,394	50,507	2,098	8,181	11,464	35,833	1,374	5,271	458	1,221
1963	17,059	52,467	2,279	8,608	12,630	36,838	1,611	5,566	539	1,455
1964	18,854	54,263	2,838	8,989	13,512	37,731	1,904	5,901	600	1,644
1965	20,044	56,437	3,093	9,415	14,185	38,892	2,103	6,343	663	1,787
1966	21,846	58,571	3,220	9,750	15,548	40,187	2,345	6,766	733	1,868
1967	23,146	60,938	3,396	10,131	16,385	41,638	2,594	7,238	771	1,931
1968	24,605	62,633	3,494	10,375	17,429	42,631	2,868	7,543	814	2,084
1969	25,631	62,888	3,503	10,131	18,308	43,044	2,950	7,808	870	1,904
1970	26,134	61,934	4,079	10,284	18,067	41,928	3,072	7,818	916	1,904
1971	26,676	59,514	4,228	9,735	18,320	40,030	3,216	7,808	912	1,940
1972	28,477	58,480	4,590	9,354	19,552	39,517	3,383	7,651	952	1,958
1973	30,718	58,329	4,762	8,867	21,249	40,064	3,701	7,395	1,006	2,003
1974	32,864	58,953	4,911	8,882	22,887	40,376	3,888	7,602	1,178	2,093
1975	35,213	59,659	5,354	8,897	24,187	40,622	4,396	8,074	1,276	2,066
1976	39,018	60,275	5,769	8,120	26,997	41,705	4,876	8,339	1,376	2,111
1977	42,783	63,126	6,012	8,379	29,825	43,937	5,451	8,654	1,495	2,156
1978	48,129	66,062	6,811	8,699	33,304	46,237	6,342	8,880	1,672	2,245
1979	54,924	69,107	7,417	8,745	38,226	48,815	7,287	9,077	1,994	2,470
1980	62,583	73,205	7,632	8,928	44,505	52,376	8,296	9,431	2,150	2,470
1981	71,819	76,792	8,425	9,019	51,810	55,681	9,284	9,667	2,300	2,425
1982	80,001	80,001	9,141	9,141	58,650	58,650	9,785	9,785	2,425	2,425
1983	89,126	84,474	10,582	9,339	65,268	62,791	10,601	9,874	2,675	2,470
1984	101,116	89,580	11,572	9,461	74,800	67,346	11,744	10,169	3,000	2,605
1985	113,745	95,239	12,945	9,583	84,239	72,202	13,186	10,670	3,375	2,784
1986	119,863	100,409	13,535	9,644	88,179	76,377	14,799	11,604	3,350	2,784
1987	127,316	103,236	13,413	9,491	94,117	78,475	16,286	12,440	3,500	2,829
1988	135,231	106,156	14,281	10,025	99,422	80,016	17,953	13,286	3,575	2,829
1989	142,000	107,352	15,800	10,131	103,000	80,507	19,300	13,866	3,900	2,847
1990	150,000	108,564	16,700	10,253	108,150	80,998	21,050	14,456	4,100	2,856
1991	155,150	109,671	17,500	10,360	111,000	81,489	22,350	14,948	4,300	2,874

Source: Current dollar figures from Tables 1 and 2, deflated in terms of Battelle Cost of Research Index of Table 4.

Policy- and budget-makers in all funding sectors should note very carefully the trends in basic research, since the conduct of such research forms the basis for future economic vitality and competitiveness.

Thus, the federal government, in any attempt to maintain the vitality of our technology-based and technology-influenced economy, should continually reexamine its policies relative to (1) the support of R&D, (2) the roles of the public and private sectors, (3) the factors which enhance or impede the progress of science and technology, and (4) the commitment to science education at all levels.

A Look Toward 1992 and Beyond

While former issues of the Battelle Forecast and Analysis (through the 1983 edition) had been confined to considerations of the forthcoming year only, well-established commitments by both the federal government and industry generally have permitted a longer look at the R&D forecast. Judging from recent trends in government spending, long-term budget commitments (tempered by budget-cutting activities), and the existing overall business climate, it is estimated that 1992 sources for R&D will be:

Federal government	$ 74,210 million
Private industry	76,710 million
Colleges & universities	4,830 million
Other nonprofit organizations	2,600 million
TOTAL	$158,350 million

In addition, it is estimated that 1992 expenditures for R&D will be distributed among the four performing sectors as follows:

Federal government	$ 18,300 million
Private industry	113,000 million
Colleges & universities	22,600 million
Other nonprofit organizations	4,450 million

The overall 2.06 percent increase in funding and performance (expressed in constant 1991 dollars) will be unevenly spread among funding and performing sectors. It is expected that funding by industry will increase more

slowly than average, while university performance will increase more slowly than that in the other sectors.

The trends which pointed to a slowdown in the rate of growth, noted in the last three years' Forecasts, are expected to continue. While federal funding of R&D had increased substantially—largely influenced by defense programs—the growing federal deficit was beginning to take its toll. It was inevitable that new, and perhaps unpopular, actions would be required. To a significant degree, the Gramm-Rudman-Hollings Act has forced reductions in the rate of growth of expenditures. However, the anticipated "peace dividend" has not yet begun to have a significant impact. The prospects of making major reductions in the DoD budget and diverting the resources to other uses held more dreams than substance, largely due to the inertia of funded programs and the reluctance to cancel or curtail further procurement. Added to this, as it applies specifically to Defense programs, the recent developments in the Middle East may have the effect of obliterating even the concept of a peace dividend, at least for the duration of the situation and, perhaps, for about two years thereafter.

The picture regarding industrial R&D growth is a little more difficult to decipher, since other kinds of forces have an influence. Federal policies certainly affect industrial decision making. Action or inaction relative to increased private and corporate taxes, limited import duties or other protectionist measures, R&D tax credits, patent policy, actions relative to mergers and acquisitions, and cooperative research will continue to affect industrial commitment to R&D, as they have in the past. These generally act more as small perturbations on the more important driving forces for industrial support of research and development, namely, (1) the need to respond to competition (both foreign and domestic) and (2) the availability of funds from earlier years' sales and profits.

In addition, the effects of the overall economy and the threat of recession or worse are already contributing to a significant slowdown in industrially supported R&D.

One bright light as regards both government and industrial funding is the acceleration of interest in technology transfer and adaptation as more federal laboratories take a stronger interest in promoting their own technical capabilities. Additional funding from providers and users—perhaps through intermediary channels—will likely be forthcoming.

Increases in university self-funding and performance in the near future continue to be, in part, a consequence of increased industrial actions of the recent past. The relaxation of apparent barriers to industrial cooperation created a funding mechanism which has infused substantial additional resources to the college and university sector. Counted as the sector's "own funds," this form of R&D support and performance will most likely continue to grow slightly over the next few years. However, it is also quite possible that a period of disenchantment will set in, particularly if any of three factors comes into play: (1) if the universities feel an encroachment upon their independence and sovereignty; (2) if supporting industries are unable or unwilling to reduce research to applications and profit; or (3) if sales and profit figures for industry are such as to reduce future "endowed investments" of this type. If any of these conditions comes to pass—and the next two to three years is the critical period—the industry/academia honeymoon may be merely an anomaly in the broader picture of long-term relations.

The national commitment to continued support and growth of R&D is based upon the observation of the positive impacts of past actions. Each funding and performing sector—individually and in concert with the others—has made major contributions to the economic strength and security of the nation. Furthermore, this cooperative effort has permitted the assumption of a pre-eminent position among the nations of the world.

But as technological advances are made, a greater effort should be pursued to look at the long-term implications of R&D. There are many difficult questions that must be addressed, including considerations of the educational system, the potential displacement of skilled and unskilled laborers, the impacts of increased life expectancy, and the general changes in the delivery of goods and services. Government and business alike have a responsibility to take the longer view, to assess the impacts of technological change, and to develop alternative postures that can assure that the benefits of technological change can be realized without serious disruption to the society.

The trends noted in this year's forecast suggest a less-than-optimistic outlook for the support of research in the near future. To be sure, there is every reason to believe that the combined effects of the Federal Budget and a business slowdown foretell very small real increases—and perhaps even decreases—in R&D expenditures. However, the bright note is that a zero or negative growth rate in R&D is not expected to last nearly as long as that of the early 1970s. In that case, about eight years elapsed, on average, for the R&D levels to reach their previous highs. Unless something completely unexpected occurs—such as a lengthy conflict in the Middle East, collapse of the banking system, or a

total absence of rationality with regard to the Federal Budget—the turnaround time should be substantially less, perhaps on the order of four years.

We are presently encountering a few speed bumps on an otherwise unfettered road.

The Need for Better Data

Industrial Line-of-Business R&D

Over the past several months, the theme of "competitiveness" continued its popularity. Along with "restructuring," "reindustrialization," and "infrastructure," this theme is likely to dominate discussions related to trade, economic growth, and any "new horizons" that will characterize the stand of the new administration. We do not expect the concept to be merely a popular buzzword, for it carries significance that was of concern long before the popularization of the word itself.

Earlier, we alluded to the difficulties associated with attempts to analyze industrial expenditures on R&D. The most readily available statistics—including those from the NSF surveys, the former DRI/McGraw-Hill surveys, and the SEC 10-K forms—make no distinctions among R&D commitments to various lines of business. Chemicals research conducted by companies in the petroleum industry is not reflected in the statistics that refer to the broad industrial class of "chemicals." Conversely, petroleum-related research conducted by the chemical companies is not included in figures that presumably represent "petroleum research." As automotive companies devote significant funds to electronics and computer research, as tobacco companies acquire food processing and distribution concerns, and as both inter- and intra-industry mergers or acquisitions occur, there is continued erosion of our understanding of the distribution of R&D and the factors that influence trends.

Industry R&D managers have long felt the need for more detailed information as it applies to their own commitments to R&D, the distribution of limited resources (both dollars and personnel), and the optimization of the R&D operation. The information needs include not just a compilation of their own efforts, but also a comparison between their own statistics and those that represent the industry as a whole. Without more detailed information regarding the trends among critical ratios in the various lines of business for which an R&D manager is responsible, the decision-making process is impaired.

As a result of this need, and recognizing the risks involved with individual attempts to gather data, Battelle has initiated projects that provide the type of analyses and comparative information that is an integral part of the resource management process. Starting with the petroleum industry, and expanding this to others, a procedure has been developed that addresses the basic information needs while avoiding the complications that would be faced by individual companies.

At the present stage of development, the approach provides line-of-business detail on relative expenditures and personnel levels devoted to R&D, technical services, and technician support; leading and lagging relations between R&D and sales, earnings and capital expenditures; and correlations between the R&D indicators and other measures of company activity, including materials or finished product throughput.

These are the types of data that assist individual companies in improving their own competitive position in setting internal R&D policy, and in providing the input necessary to integrate R&D with the larger strategic planning and analysis process.

The expansion of the approach to other industries, including chemicals, automotive, paper and wood products, ceramics, pharmaceuticals, information processing (including hardware, software, peripherals, etc.), composites, polymers, and the like, is expected to provide a better picture of the trends within R&D and a more nearly accurate accounting of the distribution of R&D effort. In addition, extension of the study to include both U.S. and foreign R&D efforts will give a truer picture of the competitive position of U.S. industry.

The basic nature of the program is such that the outputs of these surveys and analyses are generally proprietary, and information has thus far been provided only to the participating companies. To the extent that broad average values and trends can, by agreement with the participants, be made available, selected data will be included in future issues of the Battelle Forecast.

International Comparability

While intra-industry comparability is useful for assisting individual companies to analyze their competitive position and develop R&D strategies to meet future markets, international comparability is often sought as a means of determining whether total U.S. efforts will result in maintaining a preferred position relative to future trade and economic strength. Broad statistics on total R&D, selected comparisons on R&D in various functional areas, and estimates of R&D as a ratio to GNP or equivalent are usually available through the National Science Foundation, the

Organization for Economic Cooperation and Development, and other agencies.

The numbers that describe total U.S. and foreign R&D efforts are instructive to the extent that they permit general assessment of the relative commitment to R&D and some insights into the distribution of total R&D resources among various functional areas. However, these types of data are of relatively little value when attempting to formulate policies or approaches that must be translated into specific actions. The total value of R&D investment provides no more detail on the national scale than does the total value of R&D as reflected in the industrial R&D quoted in the sources cited in the previous section. That is, total values tell you everything while telling you nothing. They provide gross statements relative to national expenditures, but they say nothing about the structure of the R&D effort, the relationships among supporting and performing sectors, and the manner in which these relationships change as a result of policy actions.

In its simplest structure, the U.S. data, as presented by NSF and Battelle, consider the four major source/performer sectors of federal government, industry, colleges and universities, and other nonprofit organizations. Support for the Federally Funded Research and Development Centers (FFRDCs) is usually separated only for those FFRDCs managed by colleges and universities, while that for FFRDCs managed by industry or nonprofit organizations is generally absorbed into the total values which represent these sectors. Furthermore, as has been noted earlier, the R&D support provided by subnational units of government (such as direct support to the state universities) or through endowments or other gifts to R&D-performing institutions is not isolated, but is absorbed under the category of "own funds."

Although the situation is not perfect elsewhere, Battelle's preliminary analyses have shown that other countries' statistical efforts are more disaggregated. They permit inspection of more detailed relationships between the various classes of supporters and performers of R&D, and—taken to the most logical conclusion—they provide the background tools that are necessary for sensible policy development and evaluation. For example, nowhere in the U.S. collection of R&D statistics is there a continuing measure of the interactions between industry (as a supporter of R&D) and the federal laboratories (as a performer); the industry/federal cell of Table 2 is *defined* as being empty, while it is known that a nonzero entry should be made. Thus, there is no well-defined measure of the extent to which the Stevenson-Wydler Act and the subsequent Technology Transfer Acts of various years have been effective in promoting this interaction.

Furthermore, there is no isolation of the contributions made by state governments to the general conduct of R&D in the state universities or the specific R&D projects done on behalf of state government. And as a final example, there is no continuing data base that provides insights into the distribution of industrially supported R&D into cooperative programs or the separation between industry-funded work that is carried out in an industry's own laboratories as compared with that carried out in other industries' facilities.

While not all of the detail available in other countries' data may be necessary for the U.S. setting, it is obvious that the U.S. statistics provide only limited value relative to policy development. As the issue of competitiveness continues to be raised in political circles, industrial policy, and trade discussions, and as concern for long-term economic strength transcends mere political expediency, efforts should be directed toward improved understanding of the relative position of the U.S. R&D enterprise and toward assuring that the policy debate takes place in an environment of knowledge. Furthermore, efforts should be made to learn the lessons of history as they apply to the future.

TECHNICAL APPENDIX

NSF Definitions of Research and Development

Many activities, from one viewpoint or another, may be termed "research and development." The National Science Foundation (NSF) has, since its inception, been concerned with both the definition and the measurement of R&D. We probably can do no better than again quote the most recent definitions that the NSF has evolved. By these definitions, we can say:

"*Research and development*...consist of basic and applied research in the sciences (including medical sciences) and in engineering and activities in development....

"*Research*, which encompasses both basic and applied, is systematic, intensive study directed toward fuller scientific knowledge of the subject studied.

"*Basic research*. For three of the sectors—federal government, universities and colleges, and other nonprofit institutions—the definition of basic research stresses that it is directed toward increases of knowledge in science with...a fuller knowledge of understanding of the subject under study, rather than a practical application thereof. To take account of an individual industrial company's commercial goals, the definition for the industry sector is modified to indicate that basic research projects represent...original investigations for the advancement of scientific knowledge...which do not have specific commercial objectives, although they may be in fields of present or potential interest to the reporting company.

"*Applied Research*. The following is the core definition in the NSF questionnaire sent to the universities and colleges: '*Applied research* is directed toward practical application of knowledge.' Here again, the definition for the industry survey takes account of the characteristics of industrial organizations: It covers '...research projects which represent investigations directed to discovery of new scientific knowledge and which have specific commercial objectives with respect to either products or processes.' By this definition, applied research in industry differs from basic research chiefly in terms of objectives of the reporting company.

"*Development*. The NSF survey concept of development may be summarized as '...the systematic use of scientific knowledge directed toward the production of useful materials, devices, systems or methods, including design and development of prototypes and processes.'"*

* National Science Foundation, *National Patterns of R&D Resources*. 1953–78/79. NSF 78–313, p. 25.

Corporate headquarters are located in Columbus, Ohio

Putting technology to work is at the heart of Battelle's worldwide activities. Battelle's staff—with its broad range of scientific, technical, and management backgrounds—assists both industry and government in developing, commercializing, and managing technology.

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